

# UTILITY PATENT APPLICATION TRANSMITTAL (Large Entity)

(Only for new nonprovisional applications under 37 CFR 1.53(b))

Docket No.  
SAR 12428

Total Pages in this Submission

## TO THE ASSISTANT COMMISSIONER FOR PATENTS

Box Patent Application  
Washington, D.C. 20231

Transmitted herewith for filing under 35 U.S.C. 111(a) and 37 C.F.R. 1.53(b) is a new utility patent application for an invention entitled:

**HIGH PERFORMANCE EMBEDDED RF FILTERS**

and invented by:

**BERNARD DOV GELLER**  
**ALY FATHY**  
**MICHAEL JAMES LIBERATORE**  
**ATTIGANAL NARAYANASWAMY SREERAM and BARRY JAY THALER**

If a **CONTINUATION APPLICATION**, check appropriate box and supply the requisite information:

☐ Continuation ☐ Divisional ☒ Continuation-in-part (CIP) of prior application No.: \_\_\_\_\_

Which is a:

☐ Continuation ☐ Divisional ☐ Continuation-in-part (CIP) of prior application No.: \_\_\_\_\_

Which is a:

☐ Continuation ☐ Divisional ☐ Continuation-in-part (CIP) of prior application No.: \_\_\_\_\_

Enclosed are:

### Application Elements

1. ☒ Filing fee as calculated and transmitted as described below
2. ☒ Specification having 12 pages and including the following:
  - a. ☒ Descriptive Title of the Invention
  - b. ☒ Cross References to Related Applications (if applicable)
  - c. ☒ Statement Regarding Federally-sponsored Research/Development (if applicable)
  - d. ☐ Reference to Microfiche Appendix (if applicable)
  - e. ☒ Background of the Invention
  - f. ☒ Brief Summary of the Invention
  - g. ☒ Brief Description of the Drawings (if drawings filed)
  - h. ☒ Detailed Description
  - i. ☒ Claim(s) as Classified Below
  - j. ☒ Abstract of the Disclosure

**UTILITY PATENT APPLICATION TRANSMITTAL**  
**(Large Entity)**

*(Only for new nonprovisional applications under 37 CFR 1.53(b))*

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**Application Elements (Continued)**

3. ☒ Drawing(s) *(when necessary as prescribed by 35 USC 113)*
- a. ☐ Formal                      Number of Sheets \_\_\_\_\_
- b. ☒ Informal                      Number of Sheets 1
4. ☒ Oath or Declaration
- a. ☒ Newly executed *(original or copy)*                      ☐ Unexecuted
- b. ☐ Copy from a prior application (37 CFR 1.63(d)) *(for continuation/divisional application only)*
- c. ☒ With Power of Attorney                      ☐ Without Power of Attorney
- d. ☐ DELETION OF INVENTOR(S)  
Signed statement attached deleting inventor(s) named in the prior application,  
see 37 C.F.R. 1.63(d)(2) and 1.33(b).
5. ☐ Incorporation By Reference *(usable if Box 4b is checked)*  
The entire disclosure of the prior application, from which a copy of the oath or declaration is supplied under  
Box 4b, is considered as being part of the disclosure of the accompanying application and is hereby  
incorporated by reference therein.
6. ☐ Computer Program in Microfiche *(Appendix)*
7. ☐ Nucleotide and/or Amino Acid Sequence Submission *(if applicable, all must be included)*
- a. ☐ Paper Copy
- b. ☐ Computer Readable Copy *(identical to computer copy)*
- c. ☐ Statement Verifying Identical Paper and Computer Readable Copy

**Accompanying Application Parts**

8. ☒ Assignment Papers *(cover sheet & document(s))*
9. ☐ 37 CFR 3.73(B) Statement *(when there is an assignee)*
10. ☐ English Translation Document *(if applicable)*
11. ☐ Information Disclosure Statement/PTO-1449                      ☐ Copies of IDS Citations
12. ☐ Preliminary Amendment
13. ☒ Acknowledgment postcard
14. ☒ Certificate of Mailing
- ☐ First Class                      ☒ Express Mail *(Specify Label No.):* EL416489790US

**UTILITY PATENT APPLICATION TRANSMITTAL**  
**(Large Entity)**

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**Accompanying Application Parts (Continued)**

15. ☐ Certified Copy of Priority Document(s) *(if foreign priority is claimed)*

16. ☐ Additional Enclosures *(please identify below):*

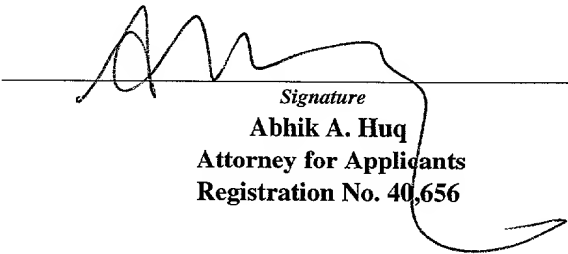
**Fee Calculation and Transmittal**

**CLAIMS AS FILED**

For	#Filed	#Allowed	#Extra	Rate	Fee
Total Claims	8	- 20 =	0	x \$18.00	\$0.00
Indep. Claims	2	- 3 =	0	x \$78.00	\$0.00
Multiple Dependent Claims (check if applicable) <input type="checkbox"/>					\$0.00
BASIC FEE					\$760.00
OTHER FEE (specify purpose) <u>Recordation Fee</u>					\$40.00
TOTAL FILING FEE					\$800.00

- ☐ A check in the amount of \_\_\_\_\_ to cover the filing fee is enclosed.
- ☒ The Commissioner is hereby authorized to charge and credit Deposit Account No. **04-0203** as described below. A duplicate copy of this sheet is enclosed.
- ☒ Charge the amount of **\$800.00** as filing fee.
  - ☒ Credit any overpayment.
  - ☒ Charge any additional filing fees required under 37 C.F.R. 1.16 and 1.17.
  - ☐ Charge the issue fee set in 37 C.F.R. 1.18 at the mailing of the Notice of Allowance, pursuant to 37 C.F.R. 1.311(b).

Dated: **29 OCTOBER 1999**

  
Signature  
**Abhik A. Huq**  
Attorney for Applicants  
Registration No. 40,656

cc:

**CERTIFICATE OF MAILING BY "EXPRESS MAIL" (37 CFR 1.10)**Applicant(s): **GELLER, B.D. ET AL.**

Docket No.

**SAR 12428**Serial No.  
**NOT YET KNOWN**Filing Date  
**HEREWITH**Examiner  
**NOT YET KNOWN**Group Art Unit  
**NOT YET KNOWN**Invention: **HIGH PERFORMANCE EMBEDDED RF FILTERS**jc525 U.S. PTO  
09/430642  
10/29/99I hereby certify that this **NEW UTILITY PATENT APPLICATION***(Identify type of correspondence)*

is being deposited with the United States Postal Service "Express Mail Post Office to Addressee" service under 37 CFR 1.10 in an envelope addressed to: The Assistant Commissioner for Patents, Washington, D.C. 20231 on **29 OCTOBER 1999**

*(Date)***Rose Macaulay***(Typed or Printed Name of Person Mailing Correspondence)**(Signature of Person Mailing Correspondence)***EL416489790US***("Express Mail" Mailing Label Number)***Note: Each paper must have its own certificate of mailing.**

## HIGH PERFORMANCE EMBEDDED RF FILTERS

## GOVERNMENT SUPPORT

5           This invention was at least partially supported by the Government Contract No. F33615-96-2-5105. The government may have certain rights in this invention.

## RELATED APPLICATIONS

10           This application claims the benefit of U.S. Provisional application Serial number 60/106,313, filed October 30, 1998.

15           This invention relates to embedded RF filters. More particularly, this invention relates to multilayer ceramic printed circuit boards including embedded RF filters having high performance.

## BACKGROUND OF THE INVENTION

20           Low temperature firing multilayer ceramic circuit boards are known that are suitable for use with low melt temperature conductive metals, such as silver, gold and copper. They have a low thermal coefficient of expansion (TCE) and they may be formulated to be compatible with both silicon and gallium  
25           arsenide devices.

          These ceramic circuit boards are made from glasses that can be fired at low temperatures, e.g., temperatures of less than 1000°C. The circuit boards are made by admixing finely divided selected glass particles or powders and optional  
30           inorganic fillers, with organic materials including resin, solvents, dispersants and the like. The resultant slurry is

cast as a thin tape, called green tape. A circuit pattern may be screen printed onto the green tape using a conductor ink formulation comprising a conductive metal powder, an organic vehicle and a powdered glass, generally the same glass as that  
5 used to make the green tape.

A plurality of green tapes having printed circuits thereon can be stacked together. In such case, via holes are punched into the green tapes which are filled with a conductive via fill ink to provide electrical contact between  
10 the circuits on the various green tapes. The green tapes are then aligned, laminated under heat and pressure, and fired to remove the organic materials and to vitrify the glass.

Recently, multilayer ceramic circuit boards have been adhered to a metal support board for added mechanical  
15 strength. A bonding glass can be used to coat the metal support and to provide adhesion between the support and the laminated ceramic layers. An added advantage to this method is that the bonding glass reduces shrinkage of the green tapes in the x and y dimensions during firing. Thus most of the  
20 shrinkage occurs in the z, or thickness, dimension. The result is that tolerances between the circuits and the via holes can be reduced. The glasses used to make the green tapes must have a TCE matched to that of the metal support to prevent delamination or cracking of the fired glass. The TCE of the  
25 green tapes can be modified by use of various metal oxide glass precursors and various inorganic fillers.

Still more recently, various passive components, such as

resistors and capacitors, have been incorporated into this ceramic circuit board system. Discrete components initially were mounted on the fired green tape stack, and wire bonded to circuitry placed about the edges of the circuit board.

- 5 Presently components such as resistors and capacitors are being printed on green tape layers where they become embedded in and part of the circuit board after firing.

Such systems can be used with RF and microwave components, particularly in the fields of personal

- 10 communication, wherein manufacturers wish to produce devices, among them hand held devices, that are small, light in weight, more reliable and less expensive than conventional devices.

One of the critical components of such systems are the provision of RF filters which are required to define and

- 15 separate RF frequency bands at radio and microwave frequencies with minimum loss and maximum selectivity. Presently such RF filters are made as discrete, surface mounted components, e.g., edge-coupled stripline resonators, which are expensive.

- Further, they take up valuable board space that could be given  
20 over to incorporation of additional functions on the board, or to reduce the overall size and weight of the ceramic circuit board.

- Embedded RF filters including strip conductors in a ceramic circuit board stack have been tried, but the  
25 performance results are no more than marginal for insertion loss and selectivity.

Thus a method of forming and embedding RF filters in a

green tape stack, that can be fired without loss of performance, has been sought.

#### SUMMARY OF THE INVENTION

Coupled shaped waveguide resonators having conducting  
5 walls are formed and embedded in a ceramic circuit board.  
These waveguide resonators have high Q values, and, by  
adjusting the size of the cavities and the permittivity of the  
ceramic, the desired operating frequency can be obtained.  
Coupling between cavities can be obtained by making apertures  
10 in the sidewalls of the cavities having a predetermined size  
and location that determine the degree of coupling.

The embedded waveguide resonators are made by forming  
three dimensional, shaped, e.g., rectangular or cylindrical,  
structures, the boundaries of which are conductive, in a green  
15 tape stack. Coupling into and out of these structures can be  
accomplished using E-plane probes which protrude through an  
opening in a top and bottom wall of the green tape stack and  
are connected on the external side to a microstrip or other  
printed transmission line. The waveguide resonators are  
20 embedded between green tapes and fired.

#### BRIEF DESCRIPTION OF THE DRAWING

Fig. 1 is a perspective view of a portion of an embedded  
RF filter of the invention.

Fig. 2 is a cross sectional view of the structure of the  
25 invention.

#### DETAILED DESCRIPTION OF THE INVENTION

The embedded RF filters of the invention comprise a



plurality of dielectric filled waveguide resonators having dimensions defined by conductors on the top, bottom and sidewalls. These volumes can have various sizes and shapes, depending on the operating frequency and resonant mode  
5 desired. The cavities are coupled together by means of apertures formed in the interior walls. The position and size of these apertures can also be adjusted depending on the degree of coupling desired.

Fig. 1 illustrates an embedded RF filter that can be made  
10 according to the present invention. Fig. 2 is a cross sectional view thereof.

Referring to Figs. 1 and 2, metal support or ground plane  
10 has a first green tape stack 12 mounted thereon having a surface 13. This green tape stack 12 is punched to provide  
15 openings for conductive walls 18 and coupling apertures 19 forming cavities 16, and openings 14 for insertion therein of E-plane probes 22. The cavity walls 18 and coupling apertures 19 are printed with a metal conductor ink to make the walls and openings 18, 19 of the cavities conductive. A conductive  
20 layer 20 can be printed over the first green tape stack 12 to form a second ground plane.

A second green tape or green tape stack 23 (Fig. 2) is mounted over the ground plane 20. Alternatively, the bottom surface of the second green tape or green tape stack 23 is  
25 screen printed with a conductive layer to form the second ground plane 20. Openings 14 are punched therein to provide for insertion of E-plane probes 22. A microstrip transmission

line 24 can be screen printed onto the top surface of the second green tape 23 over the openings 14. The first and second green tape layers 12, 23 are aligned, laminated and fired to form an embedded filter assembly.

5        Thus the embedded RF filter of the invention is made by coupling waveguide resonators formed within a ceramic substrate.

Green tapes can be made with low, moderate or high dielectric constant materials, depending on the operating  
10 frequency desired.

The metal support base 10 can be made of Kovar®, an alloy of 53.8% by weight of iron, 29% by weight of nickel, 17% by weight of cobalt and 0.2% by weight of manganese, supplied by Carpenter Technology; titanium; or a Cu-Mo-Cu laminate. The  
15 latter base is preferred for its high thermal conductivity. If the metal base 10 is coated with a dielectric, such as a bonding glass, a conductive layer forming the ground plane 10 can be printed onto the dielectric layer.

A low dielectric constant green tape is made by combining  
20 two glasses. A first crystallizing glass can be a Mg-Al-borosilicate glass. A suitable glass is made by combining 136.0 grams (34% by weight) of MgO, 52 grams (13% by weight) of alumina, 200.0 grams (50% by weight) of silica and 12 grams (3% by weight) of boron oxide.

25        The oxide powders were melted together at 1660°C for one half hour, and quenched. The glass was then ground.

A second crystallizing glass is suitably made from a

system of oxides of Mg-Al-P-B-Si. One suitable glass is prepared by mixing 124.0 grams (31% by weight) of MgO, 80 grams (20% by weight) of alumina, 188.0 grams of silica, 4.0 grams (1% by weight) of boron oxide and 4.0 grams (1% by weight) of phosphorus pentoxide. This glass was melted at 1650°C, then quenched and ground. Optionally an inorganic filler such as cordierite can also be added. The glasses are admixed with a binder and solvent to form a slurry which was cast as a green tape.

10       The green tape can be made by mixing 8 grams of the first glass described above, 190.0 grams of the second glass, 2.0 grams of cordierite, 43.0 grams of a first solution containing 846 grams of methyl ethyl ketone, 846 grams of ethanol and 112.5 grams of Menhaden fish oil, and 54.0 grams of a second  
15       solution containing 620 grams of methyl ethyl ketone, 620 grams of ethanol, 192 grams of plasticizer # 160 of Monsanto Corp. and 288 grams of B-98 resin, also from Monsanto Corp.

Moderate dielectric constant (50-100) green tapes can be made by admixing 25-75% by weight of titanium dioxide into the  
20       above glass mixture. High dielectric constant (>3000) green tapes can be made from about 90% by weight of lead magnesium niobate (PMN) mixed with about 10% by weight of lead oxide flux and similar organic binders.

The chosen slurry is cast to form green tape. Via holes  
25       are punched in the green tape, and circuitry applied by screen printing conductor inks. The via holes are filled by screen printing a conductive via fill ink. A plurality of green tapes

are then aligned to provide a green tape stack and laminated using heat and pressure in known manner. The green tape stack 12 is then punched to form openings for the walls 18, apertures 19 and openings 14 for insertion of E-plane probes

5 22. Microstrip transmission lines 24 are applied to the surface to connect to the E-plane probes 22.

A metallization ink is then used to apply a conductive layer onto the cavity bottom and to form conductive sidewalls 18 and apertures 19. A suitable silver metal conductor ink can  
10 be made by mixing 18 grams (64.6%) of silver powder, available as SPQ from Degussa Corp, 7.5 grams (16.1%) of silver flake, also from Degussa Corp, 1.50 grams (5.4%) of a resin made by dissolving 12 weight % of ethyl cellulose having a molecular weight of 300 in a mixed solvent of 50% butyl carbitol and 40%  
15 dodecanol, 3 grams of resin made by dissolving 4 weight % of ethyl cellulose having a molecular weight of 14 in the same mixed solvent, 0.45 gram (1.6%) OF Hypermer PS2 from ICI Surfactants, 0.20 gram (0.7%) of n-butyl phthalate from Fisher Chemical and 0.45 grams (1.6%) of a 50:50 lecithin-terpineol  
20 318 solvent available from Hercules Corp.

A second green tape stack 23 (see Fig. 2) having the bottom layer 24 screen printed with a metal conductor ink to form a second ground plane 20 was aligned and laminated to the first green tape stack.

25 The resultant structure was fired at a peak temperature below 1000°C.

The resultant embedded RF filters have improved

performance at lower cost than surface mounted RF filters, and they are smaller and lighter in weight than surface mounted RF filters. They are eminently suitable for hand held and other communication devices.

- 5           Although the invention has been described in terms of particular glasses and conductors, the invention is not meant to be so limited. The glasses of the various green tapes can be the same or different. Some green tapes can be made of low dielectric constant glasses, and others from mid to high
- 10   dielectric constant materials.

- Although the sidewalls of the resonators are shown as solid walls, they can also be made of metal vias to provide "picket fence posts" placed close enough together so that their spacing does not provide coupling, except for the
- 15   desired coupling apertures which are spaced more widely apart.

          The invention is thus only to be limited by the scope of the appended claims.

## I Claim:

1. A method of making embedded, coupled, shaped waveguide resonators having conductive walls sandwiched between fired green tape stacks comprising

5 mounting a first green tape stack on a metal base support substrate;

punching openings in said green tape stack to form cavity walls and coupling apertures;

forming conductive metal layers over the openings and  
10 walls;

mounting a second green tape stack over the conductive metal layers with a conductive ground plane layer therebetween, said second green tape having openings therein for insertion of E-plane probes;

15 screen printing microstrip transmission lines on the top surface of the second green tape stack so as to connect them with the E-plane probes;

aligning the green tape stacks; and

firing the resultant assembly to vitrify the glasses in  
20 the green tapes.

2. A method according to claim 1 wherein the green tapes are made from two crystallizing glasses of the Mg-Al-Silicate type, and an organic vehicle.

3. A method according to claim 1 wherein the conductor ink  
25 includes silver powder and silver flake and an organic vehicle.

4. An embedded coupled shaped dielectric waveguide resonator

having conductive walls sandwiched between two fired green tape stacks, said first green tape stack having apertures therein of a predetermined size and location to provide varying degrees of coupling.

5 5. An embedded coupled waveguide resonator according to claim 4 wherein a second metal layer is screen printed onto a green tape layer adjacent to the conductive walls.

6. An embedded coupled waveguide resonator according to claim 4 wherein the shaped waveguide is rectangular.

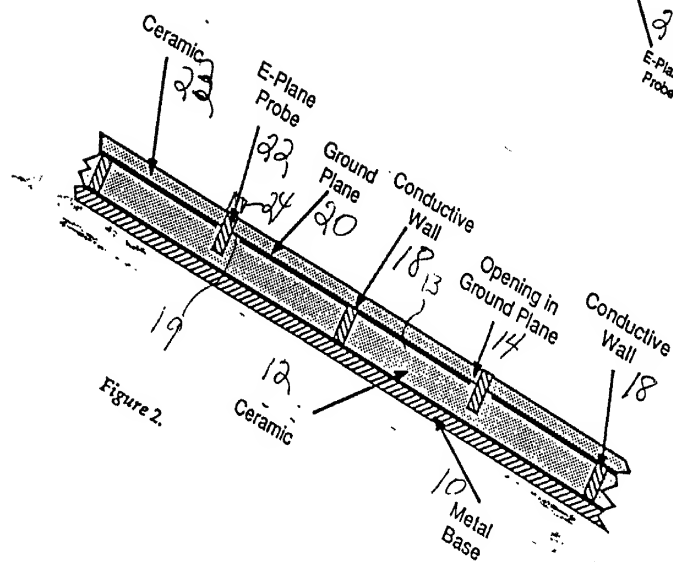
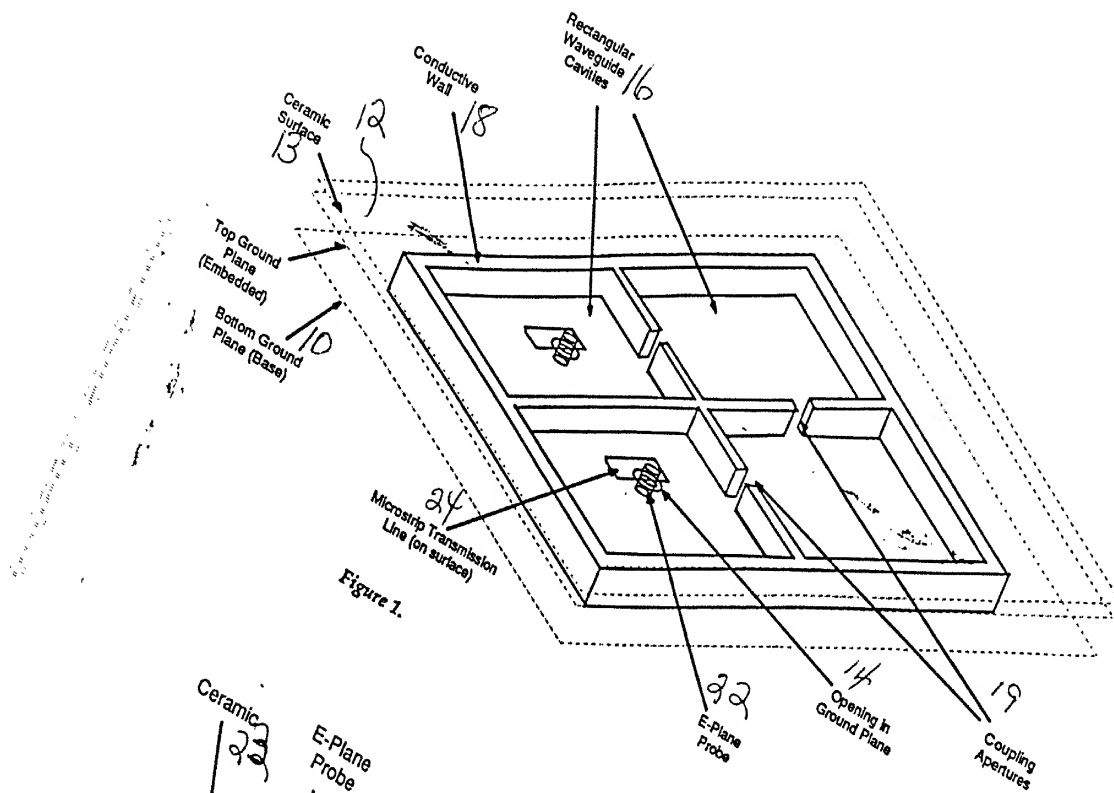
10 7. An embedded dielectric waveguide according to claim 4 wherein E-plane probes are inserted through openings in said second green tape stack and connected to microstrip transmission lines on the surface of said green tape stack.

15 8. An embedded dielectric waveguide according to claim 4 which is able to be tuned to varying operating frequencies by incorporating green tapes having varying dielectric constant into the structure.

## ABSTRACT OF THE DISCLOSURE

Embedded, coupled, shaped waveguide resonators having  
conductive walls sandwiched between two fired green tape  
stacks, said conductive walls having apertures therein whose  
5 size and location determine the degree of coupling. These  
waveguides are made by forming openings in a first green tape  
stack, defining walls and apertures therein, mounting a second  
green tape stack having a conductive layer thereon thereover  
and firing the assembly. E-plane probes are inserted in  
10 openings in the second green tape stack and connected to  
microstrip transmission lines on an external surface pf this  
green tape stack.





**COMBINED DECLARATION AND POWER OF ATTORNEY**

As a below-named inventor, I hereby declare that:

My residence, post office address, and citizenship are as stated below next to my name.

I believe I am the original, first, and sole inventor (if only one name is listed below) or an original, first, and joint inventor (if multiple names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled **HIGH PERFORMANCE EMBEDDED RF FILTERS**, the specification of which is being filed under the above-identified Attorney Docket Number.

I hereby state that I have reviewed and understand the contents of the above-identified specification, including the claims, as amended by any amendment referred to above.

I acknowledge the duty to disclose information which is material to the examination of this application in accordance with Title 37, Code of Federal Regulations, § 1.56(a).

**PRIORITY CLAIM**

I hereby claim foreign priority benefits under Title 35, United States Code, § 119 of any foreign application(s) for patent or inventor's certificate listed below and have also identified below any foreign application for patent or inventor's certificate having a filing date before that of the application on which priority is claimed.

_____	_____	_____	____ Yes ____ No
(Number)	(Country)	(Day/Month/Year Filed)	(Priority Claimed)
_____	_____	_____	____ Yes ____ No
(Number)	(Country)	(Day/Month/Year Filed)	(Priority Claimed)

I hereby claim the benefit under Title 35, United States Code § 120 of any United States application(s) listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States application in the manner provided by the first paragraph of Title 35, United States Code, § 112, I acknowledge the duty to disclose material information as defined in Title 37, Code of Federal Regulations, § 1.56(a) which occurred between the filing date of the prior application and the national or PCT international filing date of this application.

_____	_____	_____
(Application Serial No.)	(Filing Date)	(Status)
		(patented, pending, abandoned)
_____	_____	_____
(Application Serial No.)	(Filing Date)	(Status)
		(patented, pending, abandoned)

I hereby claim the benefit under Title 35, United States Code, § 119(e) of any United States provisional application(s) listed below:

**PROVISIONAL APPLICATION NUMBER**

60/106,313

**FILING DATE**

30 October 1998

**POWER OF ATTORNEY**

As a named inventor, I hereby appoint the following attorneys jointly and each of them severally, with full power of substitution, delegation, and revocation, to prosecute this application, to make alterations and amendments therein, to receive the patent, and to transact all business in the Patent and Trademark Office connected therewith:

William J. Burke, Reg. No. 29,138

John V. Silverio, Reg. No. 34,014

Abhik A. Huq, Reg. No. 40,656

I hereby direct that all correspondence and telephone calls in connection with this application be addressed to:

William J. Burke  
Sarnoff Corporation  
c/o Patent Operations  
CN 5300  
Princeton, NJ 08543-5300  
Tel. (609) 734-2560  
Fax. (609) 734-2673

#### DECLARATION

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code, and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

#### SIGNATURES

Full name of **first inventor**: Bernard Dov Geller

Inventor's signature: Bernard Dov Geller  
Date: 10/29/99 Country of Citizenship: US  
Residence and Post Office Address: **11 Kensington Court**  
**Princeton, New Jersey 08540**

Full name of **second inventor**: Aly Fathy <sup>Eid</sup> AL

Inventor's signature: ALY EID FATHY  
Date: \_\_\_\_\_ Country of Citizenship: US  
Residence and Post Office Address: **452 White Swan Way**  
**Langhorne, Pennsylvania 19047**

Full name of **third inventor**: Michael James Liberatorre,

Inventor's signature: Michael James Liberatorre  
Date: 10/28/99 Country of Citizenship: US  
Residence and Post Office Address: **208B Bakers Basin Road**  
**Lawrenceville, New Jersey 08648**

Full name of **fourth inventor**: Attiganal Narayanswamy Sreeram

Inventor's signature: Attiganal Narayanswamy Sreeram  
Date: October 28, 1999 Country of Citizenship: India  
Residence and Post Office Address: **16 Balmoral Court**  
**Edison, New Jersey 08817**

Full name of **fifth inventor**: Barry Jay Thaler

Inventor's signature: \_\_\_\_\_  
Date: \_\_\_\_\_ Country of Citizenship: US  
Residence and Post Office Address: **1 Chopin Court**  
**Lawrenceville, New Jersey 08648**